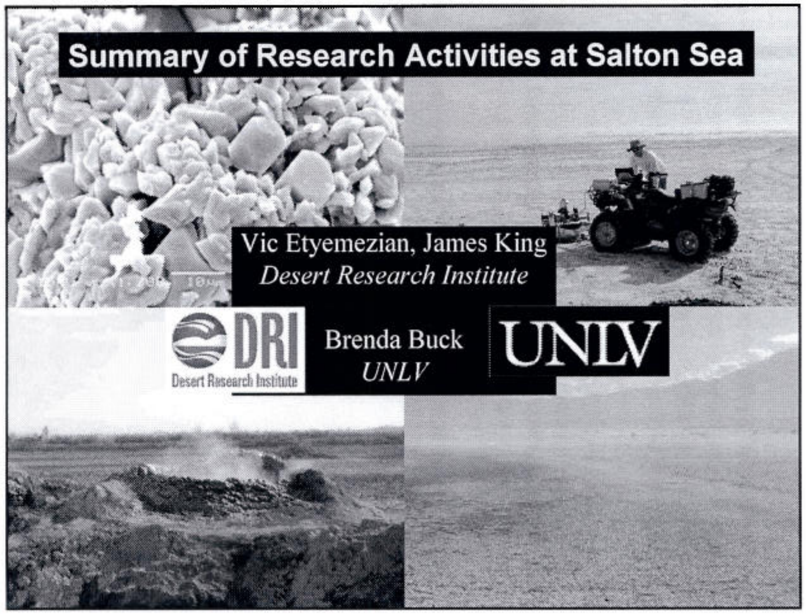

Outline

- DRI's role
- Research Conducted to date
  - Measurement of base, shoreline PM10 dust emissions (Vic Etyemezian, PI)
  - Characterization of potential playa analog sites (Mark Sweeney, PI)
  - Preliminary comparison of PM10 emissions and salt mineral characteristics (James King, PI)
- Future needs

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DRI's Role to date

- Perform field measurements of dust emissions and characterize pre-cursor conditions/surface properties
- Provide peer-review input for PEIR
- Participate in Air Quality Group meetings and discussions

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Studies completed: Seasonal variation of shoreline emissions

- Three intensive field campaigns conducted in September, January, and March (2005-2006)
- ~ 15 shoreline and near-shoreline sites around Salton Sea
- Surface characterizations: crust strength, texture, aggregate sizes, salt chemistry (bulk)
- Measurement of dust emissions at varying wind strength using PI-SWERL
  - Portable device developed at DRI
  - Not as direct as large field wind tunnels
  - Relationship between PI-SWERL and University of Guelph wind tunnel examined for Mojave surfaces

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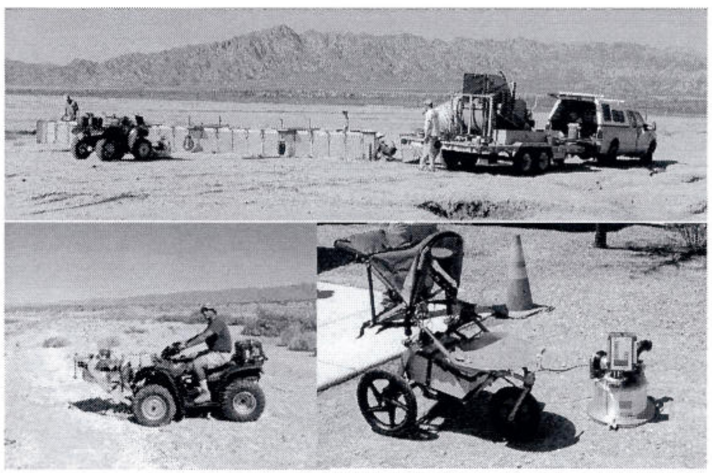
Collocation with Guelph Wind Tunnel



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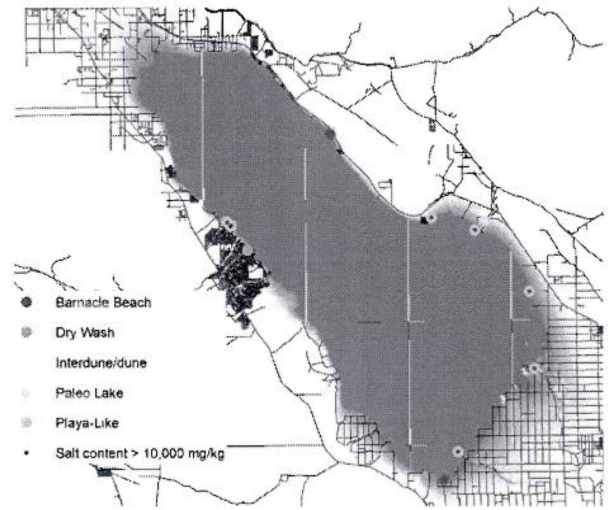
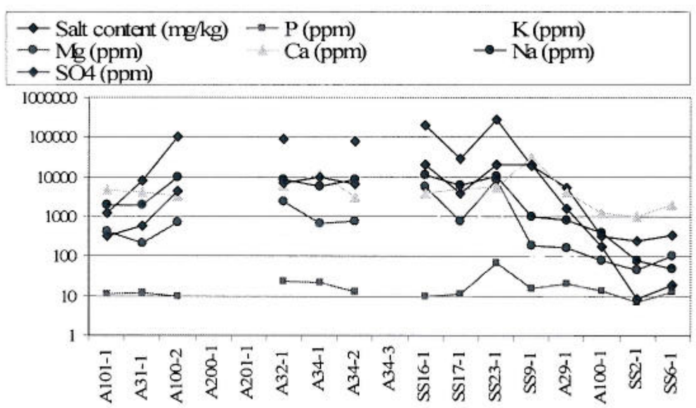
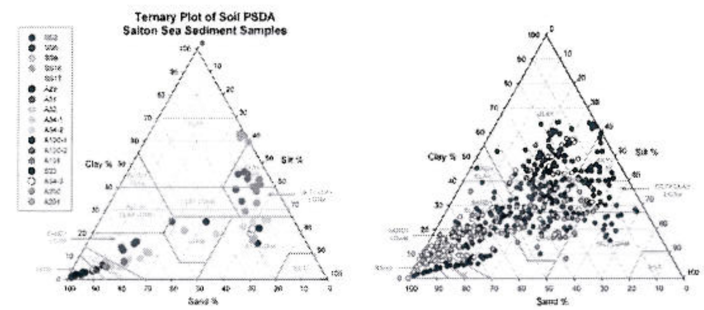
Sites



Salt Content (Sep 05)



Textures covered



Source: Agrarian Research, 2003

Sites

- Grouped by Landform:
  - "Paleo-lake", "Playa-like", "Barnacle beach", "Dry wash", and "Inter-dune"
    - "Paleo-Lake": Sediment from Ancient Lake Cahuilla
      - Silt/clay crusts
      - Some 1-3 mm snail shell deposits
      - Low Salt content (< 10,000 mg/kg)
      - 2 sites: A101, A31
    - Interdune
      - Sandy loam
      - Very low salt
      - 1 site: SS6

Sites

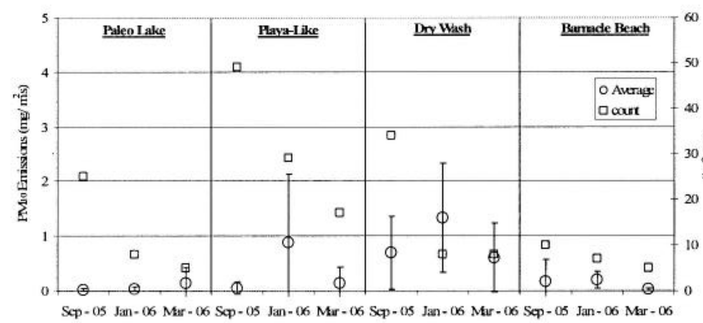
- "Playa-like"
  - Assumed to most closely resemble sediments when initially exposed as water recedes
  - Generally silt/clay or silt/loam
  - Salt content high (>10,000 mg/kg – often > 50,000)
  - 9 sites: A100-2, A200, A201, A32, A34-1, A34-2, SS16, SS17, SS23
- "Barnacle beach"
  - Low-moderate salt
  - Texture is coarse with barnacles
  - 2 sites: A29, SS9

Sites

- "Dry wash"
  - Sandy texture
  - Low salt
  - 2 sites: A100-1, SS2

Emissions by landform

$u_* = 0.56$ m/s



Summary

- Low elevation, fine-textured, "playa-like" soils appear to exhibit strong seasonality
  - Crusts weaker in winter
  - Emissions highest in winter
- Same applies to "barnacle beach" sites
- "Dry wash", "paleo-lake", and "interdune", emissions are flat, but can be high
- Comparison of Salton Sea measurements to Owens Lake indicates preliminarily Salton Sea not likely to be as emissive as Owens Lake
  - Noting major differences in methodologies, this conclusion is very tentative

Studies Completed: Characterization of potential playa analog sites

- Examine other playas in the SW U.S. to obtain range of characteristics and dust emissions
- Identify mechanistically analogous processes that may affect SS as well
- Playas Studied: Soda Lake, Silver Lake, Bristol Lake, Mesquite Lake, Ivanpah Lake, Superior Lake, Mono Lake, Owens Lake (all in California), Carson Sink (in Nevada), and Laguna Salada (Baja Mexico)

Methods

- Literature Review
  - Salt, meteorology, depth to groundwater, GW chemistry, and dust potential
- Mapping
  - 15 m LANDSAT for geomorphic mapping
- Field work
  - Reconnaissance of local geomorphology and playa environment
    - Cross-check LANDSAT imagery
  - Notes on surface crust tendencies
  - Surface samples: particle size, salt chemistry, pH, CO3
  - Some on-site PI-SWERL

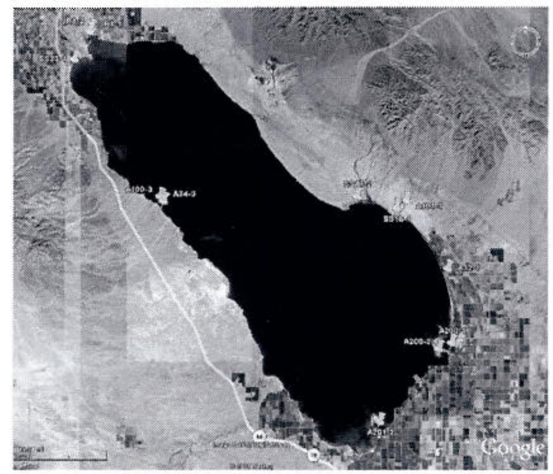
Results - Overview

- Taken altogether, playas studied cover range of conditions at SS
- But, no single analogue found
- Most emissive: Playa margins, fluvial deltaic, areas with sand dunes close to playa
  - I.e. Highest emissions found where sand available
- Weak efflorescent salts result in seasonally high emissions whereas hard crusts and vegetation suppress emissions

Preliminary assessment of PM10 emissions and salt mineral characteristics

- One intensive field visit was conducted in February 2007
- 12 shoreline and near-shoreline sites around Salton Sea – “playa-like”
- Examine surface salt composition and mineralogy of recently exposed shoreline
- Measure PM10 emissions with PI-SWERL
- Identify correlations of soil surface salt characteristics and emissions around the Salton Sea

Site Locations



DRI
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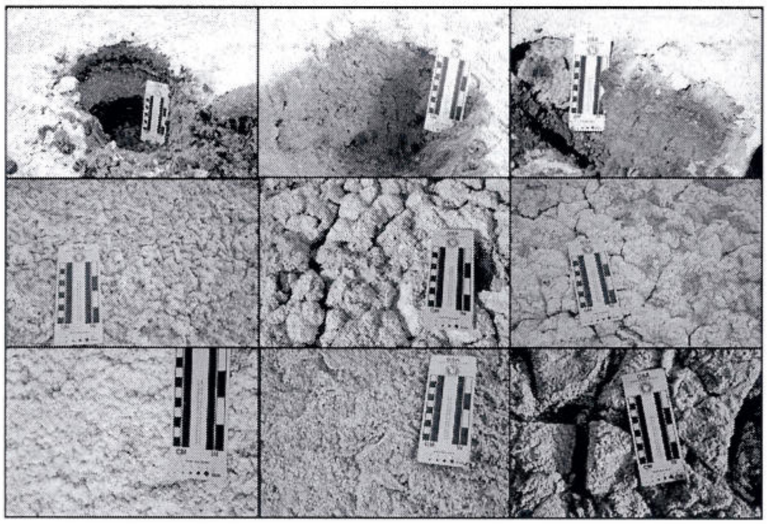

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Surface Salt Chemistry

- Soil crusts form in open systems making the use of phase diagrams (T vs. RH) ineffective to predict mineralogy
- High solubility result in large temporal and spatial variations
- Mineral assemblages and crystal habits are specific to the types of minerals in solution
- Organic matter, ion concentration, rate of crystallization, and pH also affect crystal habit
- Difficult to analyze by SEM/XRD because of often layered and soft crystal habits

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Surface Salt Mineralogy

- Mirabilite/Thernadite – Sodium sulfates
  - Hydrated/dehydrated form of sodium sulfate
  - Mirabilite more stable in cooler T and higher RH, and precipitates in tabular form
  - Thernadite precipitates in acicular form
- Eugsterite/Glauberite – Calcium sulfates
  - Hydrated/dehydrated form of sodium-calcium sulfate
  - Glauberite tends to form planar or prismatic crystals
  - Eugsterite forms acicular crystals
- Halite
  - Precipitates as many forms: euhedral cubic to anhedral massive
  - Cements other salt crystals together into hard interlocking fabric
  - Also exists as individual loose crystals

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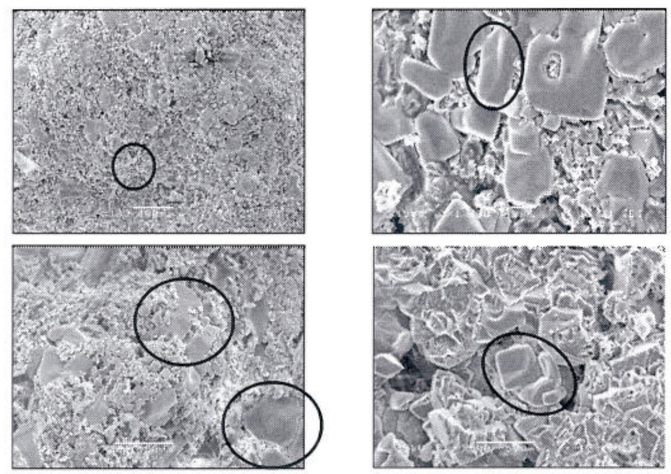
Chemistry of salts at Salton Sea

Mineral	Chemical composition	Crystal system
Halite	$NaCl$	Isometric Hexoctahedral
Eugsterite	$Na_4Ca(SO_4)_3 \bullet 2H_2O$	monoclinic
Glauberite	$Na_2Ca(SO_4)_2$	Monoclinic-prismatic
Mirabilite	$Na_2SO_4 \bullet 10H_2O$	Monoclinic-prismatic
Thenardite	Na_2SO_4	Orthorhombic-dipyramidal
Bloedite	$Na_2Mg(SO_4)_2 \bullet 4H_2O$	Monoclinic-prismatic
Hexahydrite	$MgSO_4 \bullet 6H_2O$	Monoclinic-prismatic
Gypsum	$CaSO_4 \bullet 2H_2O$	Monoclinic-prismatic
Bassanite	$2CaSO_4 \bullet H_2O$	Monoclinic, pseudohexagonal

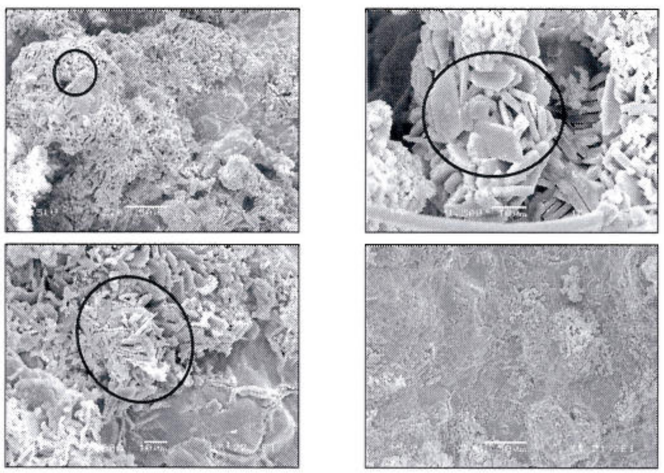
Methods

- Soil Analyses
  - XRD (X-ray diffractometry)
  - SEM (Scanning electron microscopy)
  - Texture, $CaCO_3$, EC, OC
  - Soil profiles, penetrometer,
- PI-SWERL tests
  - PM_{10} fluxes

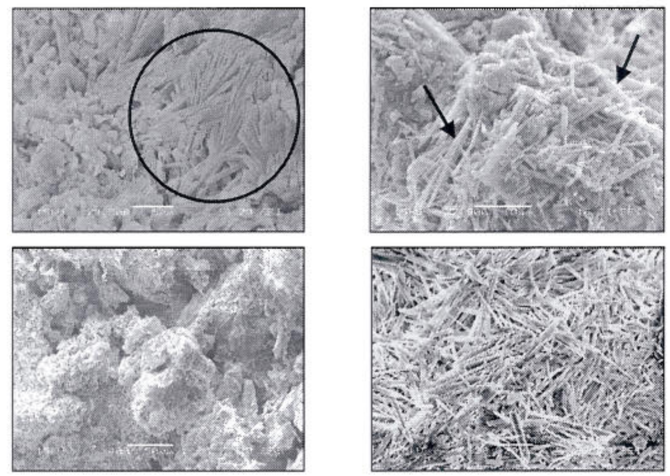
Results – SEM - Halite



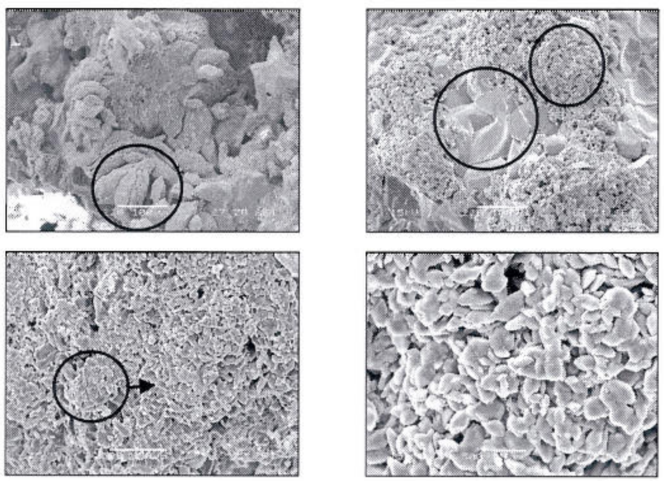
Results – SEM - Bloedite



Results – SEM - Glauberite



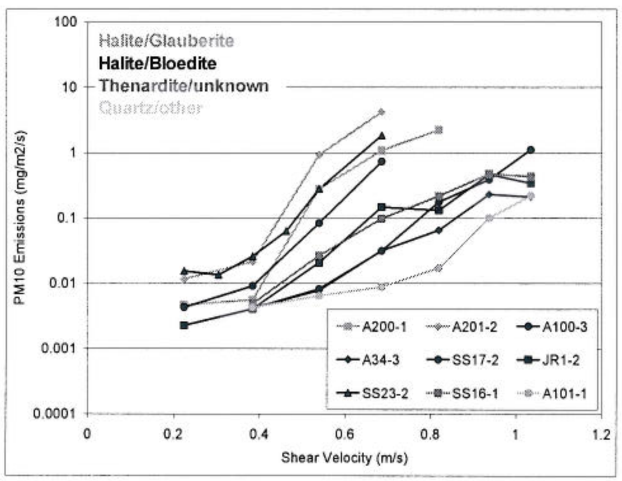
Results – SEM - Thenardite



Results - XRD

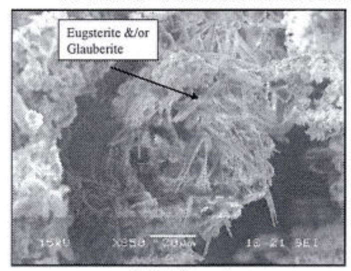
	A 100-3	A 101-1	A 200-1	A 200-2	A 201-2	A 32-1	A 34-3	JR1-1	JR1-2	SS 16-1	SS 17-2	SS 23-2
Halite	39		54	42	35	25	26	34	18	21	31	41
Bloedite	25	17	14	17	14	8	48	19	20	21	14	27
Glauberite	19		21	25	49	19						
Calcium Carbonate		8	4			13		19		10	7	9
Thenardite							16	8	5	28		
Quartz		40	6	9		7			8	3	13	
Gypsum	5		1	1	2	4	5		19		7	3
Hexahydrite						19			14		28	20
Mirabilite								19	16	18		
Eugsterite	5						6					
Bassanite				5		5						
Volkonskoite		12										
Calcium Aluminum Silicate		23										

Results – PI-SWERL

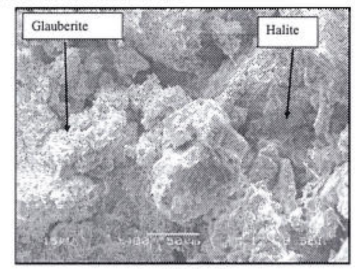


Discussion – High Emissions

- Highest emissions associated with prismatic or acicular habits (glauberite, eugsterite, thenardite) creating a loose fabric of stacked, long crystals.
- When other minerals were present (e.g., halite, gypsum) the stacks of crystals became more cemented
- Sites SS23-1 and A201-2 exhibited these characteristics



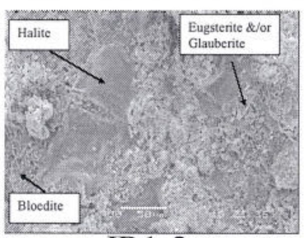
SS23-1



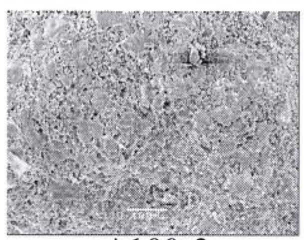
A201-2

Discussion – Low Emissions

- Low emissions were also controlled by salt mineralogy and crystal morphology
- In most cases at these sites the same minerals as the high emission sites were present according to the XRD results (greater than 5%) – BUT crystal habit was different
- Sites with low emissions with a salt crust include JR1-2 and 100-3



JR1-2



A100-3

Summary

- Genesis of friable crusts seems to be determined by the presence of water and the cycle of hydration/dehydration
- Shallow slopes and areas close to the shoreline are consistently subject to partial wetting and drying resulting in friable salt crust development over large areas
- Northern and southern halves of the Salton Sea are associated with Mg and Ca based salts, respectively

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Considerations for Future Efforts

- Why do the same minerals crystallize in different formations (habits)?
  - Wetting/drying cycles
  - Rate of shoreline retreat
  - Ion concentration, organic matter content, moisture
- What fraction of time are potentially friable crusts emissive?
  - Climatology – moisture, temperature, sunlight
  - Spatial distribution
  - Wind
- Are crust properties temporary or permanent?
  - Does prolonged drying cement/loosen initial crust properties?
- Are there engineering solutions that capitalize on these crust properties?

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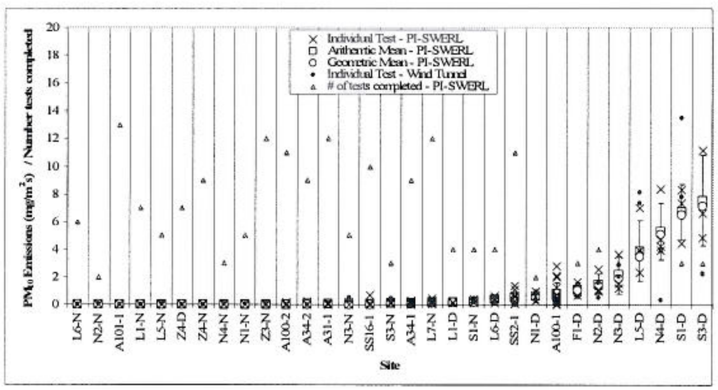
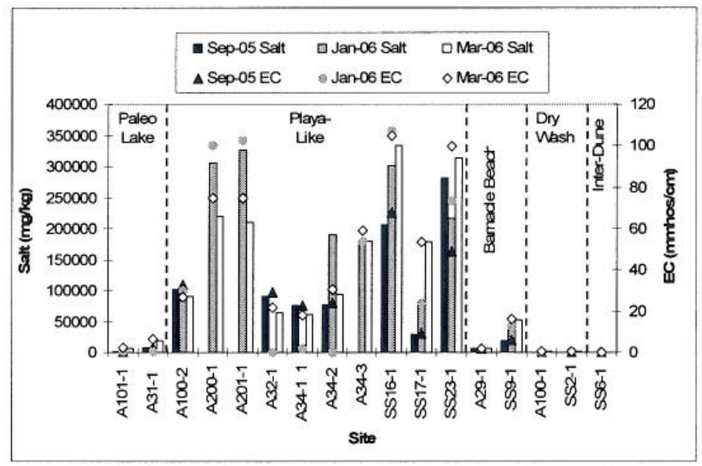
Supplemental

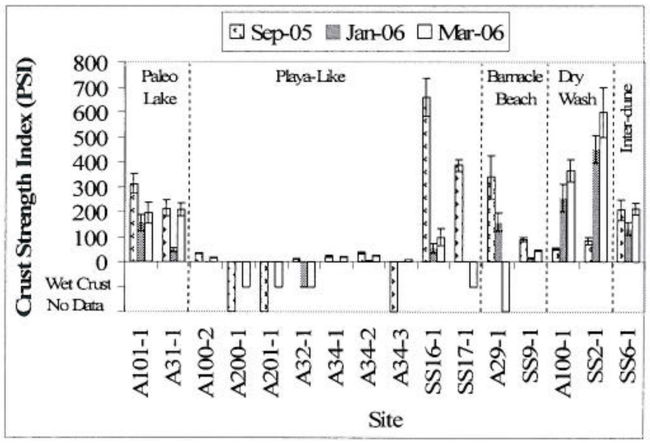
WT/PI-SWERL - Linear



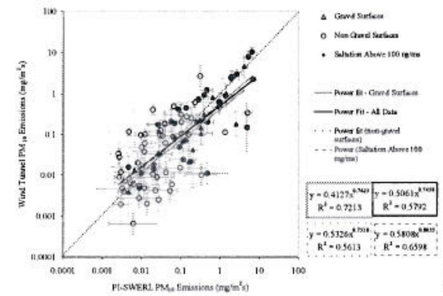
Salt by Landform

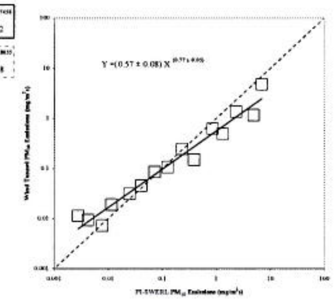


Crust properties: Spring penetrometer

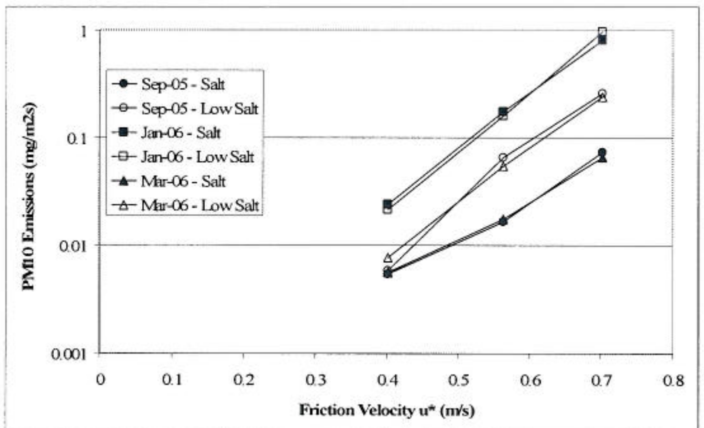


WT/PI-SWERL





Salt/ No Salt



PM10 Emissions (mg/m2s)
1
0.1
0.01
0.001
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Friction Velocity u* (m/s)
Sep-05 - Salt
Sep-05 - Low Salt
Jan-06 - Salt
Jan-06 - Low Salt
Mar-06 - Salt
Mar-06 - Low Salt